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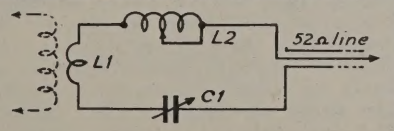
MATCHING THE GROUND-PLANE VERTICAL

By Clayton F.Bane, W6WB

The adverse effect of the sun spot cycle upon the higher frequency amateur bands has brought renewed interest in the DX possibilities of the 40 and 80 meter bands and so it is that suitable antennas for these frequencies are being given careful consideration. Probably one of the most popular types is the quarter wave vertical working against ground. (or employing a single or multiple wire radial system). It is not within the scope of this paper to discuss fully the advantages or disadvantages of this type of antenna although upon the basis of solicited reports from users it would appear that some swear by them... others at them. Vertical antennas with the high current radiating portion at approximately ground level are all subject to the same evils...reflection losses due to trees, buildings and low conductivity soil and pattern distortion due to power wires, metallic poles and towers, etc. It is thus probable that one of the reasons why some ground-plane verticals outperform others is the fact that there is a wide variation in actual height above ground as well as in the contour and conductivity of the ground surface in the vacinity of the antennas. Bear in mind that the reflection from the ground for low angles takes place at some distance from the antenna. Also that such reflection seldom takes place from the top earth surface...actually, it may take place several feet below the surface. It can be seen that all of these unknown factors make for a possible wide variation between individual antenna installations particularly as regards effective height above ground. This effective height is the determining factor in whether the major portion of the radiation is concentrated at useful DX angles or merely up into the air. Reasonable height from base of the quarter wave to ground, (somewhere between one eighth and one quarter wave would appear to be indicated unless the antenna (when erected with base at approximate ground level) is definitely out in the clear. The ground plane vertical is no "cure all" and offers no magical advantages over other verticals. It does provide a convenient method for transmission line feeding without resorting to actual connection to an earth ground. This paper is primarily concerned with methods of matching line to antenna and line to the final amplifier circuits of the transmitter.

There are numerous factors that may alter the actual impedance of the antenna at the feed point, among them being the physical length of the antenna, the length, angle-to ground and number of radials, proximity of antenna and/or radials to trees, buildings, power wiring etc. Even with such variables, the resistive term of the base impedance will probably not vary too much...possibly within limits of 25 to 50 ohms and these extremes would still afford a reasonable match for a 52 ohm line. It is very improbable however that "cut-from-formula" ground-plane antenna will present a purely resistive load to the line at the desired operating frequency and, unless some means of cancelling the reactive component is employed, it will be almost impossible to get the SWR on the line down to where it would be if the reactance were not present. Strictly aside from possible line losses, high SWR will surely have a definite effect upon the ability of the line to take load from the amplifier. Since it is readily possible to bring the SWR down to near unity, it would seem to be a logical first step to set up a line coupling circuit that will definitely load the amplifier. As mentioned previously in this and other papers, a flat 52 ohm line just doesn't want to load unless the

FIGURE 1



AMPLIFIER OUTPUT CIRCUIT

7 mcs...L1.- 4 turn pickup link, 3" diam. (same, 3.5 mcs.)
" " ...L2.- 12 turns, #10 PE, 3" diam. spaced to 6 tpi. (21 T, 3.5 mcs.)
" " ...C1.- 43 mmf. variable.....(86 mmf, 3.5 mcs.)

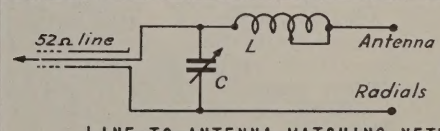


FIGURE 2

LINE-TO-ANTENNA MATCHING NETWORK

7 mcs...L.- 7 T, #10 PE, 2" diameter, 6 tpi. (12 T, 3.5 mcs.) These are maximum values, turns must be removed or shorted out for high step-down ratios.

7 mcs...C.- 100 to 700 mmf. variable or combination fixed and variable. (maximum of 1500 mmf for 3.5 mcs.)

value of Q of the pickup circuit bears a definite relation to the Q of the amplifier. Suitable output Q is readily predicted and it is fairly safe to state that a flat 52 ohm line wont provide sufficient loading with a three or four turn pickup link, (at 3.5 or 7 mc) unless a series or parallel capacitor is incorporated in the link circuit. A typical arrangement is shown in Fig.1. Note that a supplemental inductance is used to provide the required value for 3.5 mc. This assumes that a normal three or four turn pickup coil will be used. With this arrangement installed, no further concern need be given to loading. The next step is to insure a non-reactive load for the transmission line.

There are several different approaches to providing a non-reactive load for the line, all equally effective. First however, provide your self with a co-ax bridge for 52 ohms since it is safe to state that, regardless of the method used, minimum SWR will be the best criterion of proper adjustment of the antenna. The initial step is to make a frequency run from low to high through the band in an attempt to find some one point where the SWR will drop to a minimum and rise again as the frequency is further increased. This minimum value of SWR will be the lowest you can expect and indicates, within close limits, the degree of resitive mismatch between antenna feed point and transmission line. If this proves to be low (say 1.5 to 1 or less) and if it occurs close to where you plan to operate, you are all set. If it occurs higher in frequency, the antenna is too short...if lower, too long. The obvious steps should be taken...change the length of the antenna until the minimum SWR occurs at the operating frequency. Alternately, if it is impractical to change the physical dimensions of the antenna, add a capacitor in series with the antenna if the minimum SWR occurs lower than the desired operating frequency, adjusting this capacitor for minimum SWR. If the antenna is too short a variable inductor must be used. It is of interest to note that in many cases a very close match to a 52 ohm line is possible by merely lengthening the vertical beyond the quarter wavelength point.

As the length of the antenna is increased beyond this point, the resistive term of the base impedance likewise increases. The antenna of course becomes reactive but this reactance can be cancelled with a series capacitor. In other words, increase antenna length and adjust with the series capacitor until the SWR gets down near to unity.

In using series capacitors remember that the reactance at the base of the antenna may be small and this will require a series capacitor having a high value. (perhaps several hundred micro-microfarads at 80 meters.)

Simple matching networks can also be used to excellent advantage for matching line to antenna and, when properly tuned and adjusted, can provide an exact impedance transformation to insure unity SWR. They have an additional advantage in that it is generally possible to juggle the L/C network values until any reactance present in the feed point of the antenna is cancelled out as far as the transmission line is concerned. Take for example, the simple "L" network shown in Fig.2. In theory, the shunting capacity is connected across the high value of impedance, (line or antenna) and acts to transform the higher impedance to that of the lower. The series inductor acts to cancel out a capacitive reactance introduced by the shunt capacitor and thus provides a purely resistive network. It can be readily seen that additional reactance present at the antenna feed point, (due to the antenna being resonant at some frequency removed from that of the design frequency of the network) can be cancelled out by increasing or decreasing the series inductance of the network. This can only be carried to a certain point...conceivably, the antenna reactance might be such as to cancel the entire inductance and still leave a reactive term. This condition will not arise if the vertical is initially cut to within a few percent of the operating frequency.

The situation can also arise where the antenna base impedance is higher than that of the line, In this case, the network will be reversed, i.e., the inductor will be in series with the line, the capacitor from antenna base to ground-plane radials. (And outer co-ax). Reactance present in the antenna can then be cancelled, (within the limits stated) by adjustments of the shunting capacitor.

Since the exact value of antenna base impedance is generally unknown, both L and C should be variable. The constants given provide reasonable starting values and no trouble should be experienced. These networks can best be tuned by observing the SWR on the line and adjusting both L and C. That is, adjust C for minimum SWR for each value of L until a final value of inductance is found where C will drop the SWR to unity. These networks cannot be adjusted by observing the loading on the final. Adjustment with a co-ax bridge is almost infallible and once the proper network values have been determined, excellent performance can be expected over approximately 25 kc.. plus or minus the design frequency, (at 7 mc) in spite of the fact that the L network shown is essentially a single frequency device.

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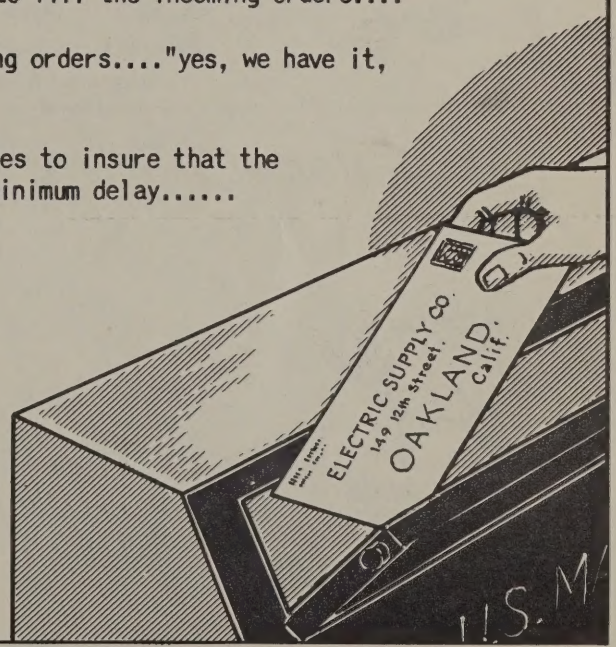

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